Variability in Size and Age at Sexual Maturity of Haddock *(Melanogrammus aeglefinus)* on the Scotian Shelf in the Northwest Atlantic

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May 1983

Canadian Technical Report of Fisheries and Aquatic Sciences No. 1168

Canadian Technical Report of Fisheries and Aquatic Sciences

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Cat. No. Fs 97-6/1168 ISSN 0706-6457

ABSTRACT

Beacham, Terry D. 1983. Variability in size and age at sexual maturity of haddock (Melanogrammus aeglefinus) on the Scotian Shelf in the Northwest Atlantic Ocean. Can. Tech. Rep. Fish. Aquat. Sci. 1168: iv + 33 p.

Variability in the median length and age at sexual maturity of haddock (Melanogrammus aeglefinus) on the Scotian Shelf was investigated. Median length at sexual maturity derived from Canadian groundfish surveys remained relatively constant among areas between 1958-1979, generally ranging between 38 to 40 cm for males and 40 to 43 cm for females. Median age at maturity generally declined during 1959-1964 to 1975-1979, from an average of 3.9 yr to 2.7 yr for males and 4.4 yr to 3.0 yr for females in the 1970s. Males matured at younger ages and smaller sizes than did females. During 1975-1979, virtually all haddock age 5 and older were mature in all areas examined. The decline in median age at sexual maturity may be due to the commercial fishery removing those individuals from the populations that mature at older ages, a general decline in stock biomasses between 1960-1975 due to heavy exploitation and increased growth rates, or both hypotheses may apply.

Key words: age, exploitation, haddock, maturity, population dynamics, Scotian Shelf, size.

RESUME

Beacham, Terry D. 1983. Variability in size and age at sexual maturity of haddock (Melanogrammus aeglifinus) on the Scotian Shelf in the Northwest Atlantic Ocean. Can. Tech. Rep. Fish. Aquat. Sci. 1168: iv + 33 p.

La présente étude porte sur la variabilité de la longueur et de l'âge médians à la maturité sexuelle de l'aiglefin (Melanogrammus aeglefinus) peuplant la plate-forme Scotian. Selon les levés canadiens sur le poisson de fond, la longueur médiane à la maturité sexuelle est demeurée relativement constante de 1958 à 1979 dans les zones étudiées. En général, elle varie de 38 à 40 cm et de 40 à 43 cm chez les mâles et les femelles respectivement. L'âge médian à la maturité a généralement baissé au cours des périodes 1959-1964 et 1975-1979; il est passé de 3,9 à 2,7 ans chez les mâles et de 4,4 à 3,0 ans chez les femelles dans les années 1970. Les mâles ont atteint la maturité plus jeunes et plus petits que les femelles. De 1975 à 1979, presque tous les aiglefins de 5 ans ou plus étaient matures dans les zones étudiées. Cette baisse de l'âge médian à la maturité sexuelle peut être causée soit par la pêche commerciale qui enlève des populations les individus qui atteignent la maturité à un âge avancé ou par un déclin général des biomasses des stocks entre 1960 et 1975 par suite d'une surexploitation et de taux de croissance élevés, ou les deux hypothèses à la fois.

Mots-clés: âge, exploitation, aiglefin, maturité, dynamique des populations, plate-forme Scotian, taille

INTRODUCTION

Vertebrate population dynamics are determined by the combined effects of reproduction, growth, dispersal, and mortality. The median age at which individuals attain sexual maturity has a significant impact upon the potential for population growth (Cole 1954; Stearns 1976). Growth rates of individuals and reproductive potential of a population are linked by the size and age at which individuals attain sexual maturity, and therefore these parameters are of importance in a general investigation of population dynamics.

Haddock (Melanogrammus aeglefinus) has been one of the most sought after finfish species in the Atlantic region of Canada. Heavy exploitation in the 1950s and 1960s resulted in declines in stock biomass of many haddock stocks in the Northwest Atlantic (Halliday 1971; Templeman et al. 1978a; Templeman and Bishop 1979a; O'Boyle MS 1980). In the Northwest Atlantic Fisheries Organization Subarea 4, haddock were exploited in the southern Gulf of St. Lawrence (Div. 4T) (McCracken 1963) and the Scotian Shelf (Halliday 1971; O'Boyle MS 1980) (Fig. 1). The Canadian fishery for haddock is presently most extensive off southwestern Nova Scotia in Div. 4X (O'Boyle MS 1980).

Spawning biomass of a stock is of direct concern in the management of a fishery, and can be evaluated when the abundance and proportion mature at each age is known. The presence of haddock on the Scotian Shelf (McCracken 1960, 1963; Grosslein 1962; Halliday and McCracken 1970) and its commercial importance presented an opportunity for an investigation of regional variability in median size and age at sexual maturity. The major purpose of this paper is to present historical changes in median size and age at sexual maturity and to attempt to account for some of this variability among haddock in different areas.

MATERIALS AND METHODS

The data analyzed in this paper were collected between 1958-1979 during groundfish surveys of the M/V HARENGUS, E.E. PRINCE, and A.T. CAMERON. Haddock on the Scotian Shelf have been sampled since 1970 during July cruises of the A.T. CAMERON. Stratified random design groundfish surveys were initiated in all areas surveyed in 1970. For the present analysis, annual values for median (50% mature point) length and age at sexual maturity of haddock on the Scotian Shelf before 1970 were calculated from any survey during the summer, not only July. The period of peak spawning of Scotian Shelf haddock is in April (Grosslein 1962). Maturity ogives based on length and age were calculated for four periods in the study, each corresponding to about a 5-yr interval. All surveys conducted in each interval were included in the calculation of the maturity ogives. Details of the surveys such as

vessels and gear used and areas surveyed were outlined by Halliday and Koeller (1981). Fork length (cm) and maturity stage of haddock were recorded at sea, and otoliths saved for later age determination according to the method of Kohler (1964). Kohler (1958) demonstrated the validity of using otoliths for age determinations in haddock. Powles (1958) outlined the classification of the gonads used in assessing maturity stage.

The transition from the immature to the mature condition in fish usually occurs over a range of length and age in the form of a sigmoid curve. From the percentages of mature haddock (gonads in ripening, ripe, spawning, spent, or recovering condition) in 2-cm length intervals in a survey or period under consideration, the median length at sexual maturity was calculated by probit analysis following the technique of Leslie et al. (1945). Median age at sexual maturity was calculated by probit analysis by grouping the data in 1-yr intervals. However, in some cases, annual values for median size and age at sexual maturity could not be calculated because haddock were not sampled in that year or because so few haddock were sampled that the data were not available in sufficient quantity for probit analysis.

RESULTS

SUBDIVISION 4Vn

Haddock in the 1970s attained sexual maturity at younger ages ($P<0.05$) than did haddock between 1959-1964 (Table 1). There was, however, no significant difference in size at maturity ($P>0.05$). Median lengths at maturity during 1959-1964 were 41 cm for males and 47 cm for females, whereas in the 1970s these fork lengths were 40 cm and 41.5 cm respectively. Over 99% of females were mature by 50 cm in length in the 1970s, but only about 70% were mature between 1959-1964 (Fig. 2). Males matured at smaller sizes and younger ages than did females (Table 1). During 1959-1964, median age at maturity for males was 3.6 yr and for females 4.4 yr, and in the 1970s these ages were 3.2 yr and 3.5 yr respectively ($P<0.05$).

SUBDIVISION 4Vs

A greater quantity of data was available for haddock caught in Subdivision 4Vs than in 4Vn. It was therefore possible to examine annual variability in median age at sexual maturity. After 1972, however, sample sizes were too low to investigate annual trends. Median age at maturity during 1959-1965 was about 3.8 yr for males and about 4.3 yr for females. Median ages at sexual maturity calculated for 1972 were 2.8 yr for males and 2.6 yr for females (Fig. 3).

Maturity ogives based on length indicated a rather stable pattern between 1959-1979, with some evidence of larger, immature haddock less frequent during 1975-1979 than earlier. Median lengths at sexual maturity remained constant at about 39 cm for males, but declined significantly ($P<0.05$) in females from about 44 cm in 1959-1964 to about 38 cm during 1975-1979 (Fig. 4).

Although the maturity ogives based on length were relatively constant through time, the percentage mature at age increased with time (Table 2). Most of the change occurred in ages 3 and 4, with the percentage of mature age-3 females eight times higher during 1975-1979 than during 1959-1964. Median ages at maturity for females declined from about 4.3 yr during 1959-1964 to about 2.7 yr during 1975-1979 ($P<0.05$), while those for males declined from 3.8 yr to 2.8 yr respectively ($P<0.05$), which indicates a faster rate of decline in median age at maturity in females than in males.

DIVISION 4W

Although there was some annual variability in median length at sexual maturity, there was no unidirectional trend, with the values for 1978 and 1979 generally below the long-term average (Fig. 5). Median ages at maturity were relatively constant until about 1965, after which they have tended to decline (Fig. 6). Males generally attained sexual maturity at smaller sizes and younger ages than did females. For females, median age at maturity was above 4 yr until 1969, after which it rapidly declined to slightly greater than 3 yr in the 1970s.

Maturity ogives based on length and age were calculated for the four periods analyzed in this study, and the transition from the immature to the mature state followed a sigmoid curve. As in haddock in other areas, median lengths at sexual maturity have remained relatively constant, at about 38 cm for males and 42 cm for females (Fig. 7). There was little change in the lengths at which 0% and 100% of the males and females were mature through time.

The stability of the maturity ogive based on length was contrasted by the general increase in percentage mature at age through time (Table 3). As in haddock in Subdivision 4Vs, this increase was most marked in ages 3 and 4, with the percentage of mature age-3 females over nine times larger during 1975-1979 than during 1959-1964. Median ages at maturity for males declined from about 3.9 yr during 1959-1964 to about 2.8 yr during 1975-1979 ($P<0.01$), while those for females declined from 4.4 yr to 3.1 yr during the same interval ($P<0.01$). The rate of decline in median age at maturity was again greater in females than in males. Variability in percent mature by age for females was also investigated by year-class. The percent mature at age 4 increased from 34% in the 1954 year-class to 96% in the 1975 year-class (Table 4). In 1965, 2% of the females in the 1962 year-class were mature, but by 1967 all were mature. Similarly, in 1965, 0% of the females in the 1963 year-class were mature, but 38% were mature in 1966. Thus there was a rapid increase in percent mature by age during 1966-1967 as compared with 1965. In 1978, 52% of the females in the 1976 year-class were mature, but only 50% were classified as mature in 1979. The value in 1978 seems unusually high, and as

there was also a rapid decline in length at maturity in 1978, would seem to indicate that there was a difference in maturity interpretation in 1978, so that the proportion of maturing age 2 fish was probably overestimated.

DIVISION 4X

The analysis of variability in median size and age of haddock caught in Division 4X indicated that trends were similar to those of haddock in other areas. As in Division 4W haddock, there has been no unidirectional trend in median length at sexual maturity with time (Fig. 8). As in other areas, males matured at smaller lengths than did females. Although median lengths at sexual maturity have been relatively constant, median ages at maturity have declined during 1959-1979 (Fig. 9). There was a relatively rapid decline in median age at sexual maturity during 1969-1970 to about 3.1 yr for males and 3.3 yr for females.

Maturity ogives based on length for data grouped in the multi-yr blocks indicated that median lengths at maturity were about 43.1 cm for females and 40.5 cm for males during 1959-1964, but there was about a 2-cm decline in both sexes during 1965-1979 (Fig. 10). During 1965-1979, there was little change in the length at which 100% of the males and females were mature, being about 55 cm for females and 50 cm for males. Immature haddock over 50 cm were more abundant in the stock during 1959-1964 than during 1965-1979.

As in haddock in other areas investigated, there was an increase in percentage mature at age through time, the increase most pronounced at ages 3 and 4 (Table 5). The percentage mature of age-3 females was about 8 times higher during 1975-1979 than during 1959-1964, similar to the results of haddock in Subdivision 4Vs and Division 4W. Median ages at maturity for males declined from about 4.7 yr in 1959-1964 to about 2.8 yr in 1975-1979 ($P<0.01$), while those for females declined from about 4.6 yr to 3.0 yr during the same period ($P<0.01$). The decline in median age at maturity was slightly higher in males than in females.

COMPARISONS AMONG AREAS

Several trends were apparent when all areas were considered in the multi-year grouping of groundfish surveys. Median length at sexual maturity was relatively constant for males among areas and through time, generally ranging between 38 and 40 cm (Table 6). Median lengths at sexual maturity for females also showed a general static nature through time, usually ranging between 40 and 43 cm. In an analysis of trends in median age at sexual maturity, there was a trend for younger ages in maturity through time for haddock in all areas investigated. Males generally matured at younger ages than did females.

DISCUSSION

Haddock on the Scotian Shelf generally endured high rates of exploitation and declining stock biomasses in the 1960s and early 1970s (Halliday 1971; O'Boyle MS 1980). If growth rate in haddock is inversely related with stock biomass (Sonina 1965; Templeman et al. 1978b), then a decline in stock biomass would be accompanied by an increase in growth rates. If in haddock the attainment of maturity is a fixed function of length, then age at maturity would decline owing to an increase in growth rates.

Median age at maturity of haddock in Division 4W declined after 1965 (Fig. 6). Nominal catches from the 4VW haddock stock peaked in 1965, with over 50,000 metric tonnes reported by all countries, and with the Soviet Union catch reported at about 43,000 metric tonnes (Halliday 1971). Catches declined rapidly to less than 11,000 t in 1967. The decline in median age at maturity subsequent to 1965 suggests that this parameter may have been responding to a decline in stock biomass. However, stock biomasses have increased in the late 1970s (White et al. MS 1981), but there has been no corresponding increase in median age at maturity.

Variability in length and age at maturity for haddock in the northwest Atlantic has been an area of some research. Clark (1959) found that for haddock collected in March of 1949 and 1950 on Georges Bank (Subdiv. 5Ze), 0% of age-2 and 78% of age-3 females were mature, and 40% of age-2 and 98% of age-3 males were mature. Based on sampling between 1973-1975, Clark et al (1982) reported that 34% of age-2 and 92% of age-3 females were mature, with values of 74% and 98% respectively for males. Thus, median age at maturity has also declined in the Georges Bank haddock stock. Variability in median length and age at sexual maturity for haddock in the Newfoundland area was investigated by Templeman et al. (1978b) and Templeman and Bishop (1979b), who found a trend for increasing percentage mature at age between 1947-1975, and consequently a decrease in the median age at sexual maturity. This same trend was noted for haddock caught in Canadian groundfish surveys on the Scotian Shelf. Median lengths at maturity were more variable for haddock near Newfoundland (Templeman et al. 1978b; Templeman and Bishop 1979b) than for haddock in the present study. An increasing median length at maturity was ascribed to increasing growth rates (Templeman and Bishop 1979b), but as median age at maturity declined in periods of both increasing and decreasing growth (Templeman et al. 1978b), selection for early maturing fish may account for the decline in median age at maturity. Raitt (1936) found that for haddock in the North Sea, 60% of age-2 males and 10% of age-2 females were mature, although 75% of age-3 females were mature. These rates of maturity were higher than in haddock caught on the Scotian Shelf (Divsions 4VWX) between 1959-1979.

In all the haddock stocks investigated in the present study, median length at sexual maturity was relatively constant, but median age at maturity generally declined through time. To the extent that age at maturity may be determined genetically (Alm 1959), then there may have been selection for fish that mature at younger ages. This decline in median age at maturity was accompanied by an increase in growth rate, if median length at maturity remained relatively constant. In an intensive fishery as has occurred on

haddock in many areas on the Scotian Shelf since 1960, selection would favour those genotypes that reproduce at ages not fully recruited to the commercial fishery, whereas a genotype that matures at a later age might be removed before spawning. This process might contribute to the decreasing abundance of older, immature fish through time.

With the introduction of quota management strategy and improved recruitments, stock biomasses have generally increased during 1975-1979. However, there may be a lag effect if age at maturity is dependent upon growth rate and stock biomass. Pacific halibut (Hippoglossoides stenolepis) stocks recovered from low levels of population abundance with no apparent genetic change (Miller 1957). The recoveries of many groundfish stocks during periods of restricted exploitation after heavy fishing, with no apparent genetic change, suggests that environmental conditions rather than genetic changes have more influence on variability in population parameters.

In summary, the present study has indicated that median length at maturity has remained relatively constant, but median age at maturity has declined for haddock in several areas on the Scotian Shelf in the 1960s and 1970s. Males matured at younger ages and smaller sizes than did females. The decline in median age at maturity may be attributable to an increase in growth rate concurrent with a decline in stock biomass as suggested by Templeman and Bishop (1979b), but possible effects of selective fishing should be investigated as well.

ACKNOWLEDGMENTS

I am indebted to those people who have crewed the research vessels and aged the haddock. Dr. Charles J. Krebs of the University of British Columbia wrote the computer program for probit analysis. Albert Vromans ably assisted in much of the analysis. Dr. R. G. Halliday (Marine Fish Division) and Mr. Vince Hodder (NAFO) made many helpful comments on a draft of this manuscript. The manuscript was prepared with the assistance of the staff at the Pacific Biological Station.

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Table 1. Percentages of sexually mature haddock by age and sex caught during Canadian groundfish surveys in Subdivision 4Vn, 1959-1979. No data were available from 1965-1969 . Sample sizes are in parentheses after individual ages and 95% confidence limits after A_{50} (yr).

Age (yr)	1959-1964	1970-1979
	Male	
1	0.0 (16)	0.0 (7)
2	5.0 (20)	0.0 (5)
3	27.5 (69)	20.0 (10)
4	58.7 (92)	100.0 (4)
5	88.5 (61)	100.0 (4)
6	100.0 (12)	100.0 (1)
A_{50}	3.62(3.43-3.83)	3.24(2.96-3.55)
	Female	
1	0.0 (1)	0.0 (1)
2	0.0 (11)	0.0 (7)
3	12.5 (56)	22.2 (9)
4	30.3 (76)	71.4 (7)
5	73.2 (82)	100.0 (1)
6	80.7 (31)	100.0 (2)
7	100.0 (14)	100.0 (1)
A_{50}	4.40(4.17-4.63)	3.54(3.07-4.09)

Table 2. Percentages of sexually mature haddock by age and sex caught during Canadian groundfish surveys in Subdivision 4Vs, 1959-i979. Sample sizes are in parentheses after individual ages and 95% confidence limits after A_{50} (yr).

Age (yr)	1959-1964	1965-1969	1970-1974	1975-1979
		Male		
1	0.0 (21)	- (0)	0.0 (32)	0.0 (4)
2	0.0 (60)	12.5 (8)	17.1 (41)	0.0 (52)
3	19.5 (77)	30.8 (39)	50.0 (26)	66.7 (21)
4	56.9 (51)	60.0 (15)	63.3 (49)	100.0 (5)
5	90.5 (42)	100.0 (8)	92.0 (25)	100.0 (9)
6	92.3 (26)	80.0 (5)	91.7 (12)	100.0 (5)
7	100.0 (10)	100.0 (2)	100.0 (8)	100.0 (4)
A_{50}	3.78(3.59-3.98)	3.53(3.13-3.97)	3.14(2.85-3.47)	2.83(2.57-3.12)
		Female		
1	0.0 (12)	- (0)	0.0 (10)	0.0 (4)
2	0.0 (37)	0.0 (6)	12.8 (39)	3.3 (39)
3	8.5 (71)	29.4 (34)	65.7 (35)	69.6 (26)
4	30.9 (81)	48.0 (25)	51.4 (37)	100.0 (12)
5	71.4 (63)	80.0 (10)	83.3 (18)	100.0 (6)
6	98.3 (57)	100.0 (3)	94.7 (19)	100.0 (7)
7	100.0 (31)	100.0 (8)	90.0 (10)	100.0 (3)
8	100.0 (7)	100.0 (3)	100.0 (12)	- (0)
A_{50}	4.31(4.14-4.48)	3.81(3.40-4.27)	3.19(2.86-3.57)	2.74(2.53-2.98)

Table 3. Percentage of sexually mature haddock by age and sex caught during Canadian groundfish surveys in Division 4W, 1958-1979. Sample sizes in parentheses after individual ages and 95% confidence limits after A_{50} (yr).

Age (yr)	1958-1964	1965-1969	1970-1974	1975-1979
		Male		
1	0.0 (210)	0.0 (237)	0.0 (267)	0.0 (447)
2	0.7 (538)	5.8 (343)	9.5 (337)	14.8 (378)
3	18.7 (546)	32.7 (446)	59.1 (428)	56.6 (369)
4	59.3 (435)	57.2 (390)	89.2 (362)	91.0 (512)
5	83.6 (287)	89.4 (254)	99.2 (262)	100.0 (321)
6	94.4 (233)	94.0 (167)	100.0 (126)	100.0 (139)
7	97.1 (175)	99.0 (98)	95.7 (93)	100.0 (114)
8	95.1 (101)	100.0 (46)	100.0 (56)	90.0 (20)
9	91.2 (57)	100.0 (38)	100.0 (21)	100.0 (8)
10	100.0 (42)	88.9 (18)	100.0 (2)	100.0 (6)
A_{50}	3.88(3.79-3.96)	3.54(3.45-3.63)	2.83(2.76-2.91)	2.76(2.70-2.83)
		Female		
1	0.0 (140)	0.0 (166)	0.0 (225)	0.0 (448)
2	0.4 (505)	1.9 (325)	2.7 (334)	10.4 (423)
3	4.8 (566)	14.2 (430)	32.0 (306)	40.2 (463)
4	28.7 (436)	36.4 (363)	70.3 (273)	89.4 (424)
5	77.0 (344)	82.8 (268)	92.0 (200)	98.1 (261)
6	92.0 (300)	90.6 (265)	99.3 (146)	100.0 (144)
7	98.2 (280)	98.8 (173)	99.4 (168)	99.0 (102)
8	97.2 (145)	99.1 (109)	99.3 (141)	100.0 (31)
9	98.8 (83)	100.0 (63)	100.0 (49)	100.0 (12)
10	100.0 (71)	100.0 (24)	100.0 (16)	100.0 (4)
A_{50}	4.40(4.33-4.48)	4.11(4.02-4.20)	3.42(3.33-3.51)	3.11(3.05-3.17)

Table 4. Percent of female haddock classified as mature during Canadian groundfish surveys in Div. 4W for the 1952-1977 year-classes.

	Age (yr)							
Year-class	1	2	3	4	5	6	7	8
1952						93.9(33)	100.0(50)	100.0(14)
1953					90.9(11)	100.0(24)	100.0(19)	100.0(38)
1954				34.4(32)	94.6(37)	100.0(19)	92.0(25)	100.0(29)
1955			14.6 (55)	45.2(42)	90.0(20)	89.9(28)	97.6(41)	100.0(18)
1956		1.4 (73)	10.7 (75)	45.7(35)	82.0(50)	97.4(77)	96.7(30)	-
1957	0.0(51)	0.0 (60)	0.0 (21)	25.4(59)	78.2(87)	95.1(41)	-	100.0(26)
1958	0.0 (2)	0.0 (3)	3.3 (30)	29.2(24)	46.2(13)	-	91.7(12)	100.0(13)
1959	0.0 (8)	0.0(118)	5.9(102)	17.0(59)	-	79.3(29)	100.0(29)	100.0 (2)
1960	0.0 (8)	0.0 (40)	0.0 (16)	-	71.4(21)	100.0(11)	100.0 (5)	-
1961	0.0 (8)	2.4 (41)	-	20.0(20)	90.0(30)	100.0 (7)	-	100.0(15)
1962	0.0(19)	-	2.0 (50)	40.6(69)	100.0 (7)	-	100.0(36)	100.0 (6)
1963	-	0.0 (45)	38.1 (63)	66.7(18)	-	93.6(47)	100.0(18)	100.0(14)
1964	0.0 (4)	6.1 (49)	10.0 (20)	-	69.7(33)	100.0(14)	100.0 (8)	100.0 (5)
1965	0.0 (3)	0.0 (24)	-	28.1(32)	86.7(15)	100.0(11)	100.0 (5)	100.0 (3)
1966	0.0 (6)	-	7.4 (27)	63.6(55)	95.0(20)	100.0 (8)	100.0 (4)	100.0 (3)
1967	-	0.0 (29)	33.3 (57)	78.4(37)	88.9(18)	100.0(12)	100.0 (9)	100.0 (4)
1968	0.0(17)	5.9 (34)	57.6 (33)	91.3(23)	100.0 (3)	100.0 (8)	85.7 (7)	100.0 (2)
1969	0.0(75)	6.0(100)	48.7 (37)	89.5(19)	100.0(18)	100.0(26)	100.0 (6)	100.0 (4)
1970	0.0(29)	0.0 (12)	46.2 (13)	77.8 (9)	100.0(15)	100.0 (7)	100.0 (7)	100.0 (1)
1971	0.0(48)	2.0 (50)	32.7 (49)	88.4(43)	100.0(37)	100.0(19)	100.0 (5)	100.0 (4)
1972	0.0(21)	0.0 (34)	66.1 (56)	93.9(33)	97.6(41)	100.0 (9)	100.0 (5)	
1973	0.0 (5)	0.0 (14)	8.3 (12)	85.7(14)	100.0 (6)	100.0(12)		
1974	0.0(87)	5.5 (73)	42.7 (75)	97.5(80)	96.3(54)			
1975	0.0(87)	4.0 (75)	87.7 (81)	95.5(88)				
1976	0.0(66)	53.0 (66)	50.0 (62)					
1977	0.0(74)	4.6 (87)						

Table 5. Percentages of sexually mature haddock by age and sex caught during Canadian groundfish surveys in Division 4X, 1959-1979. Sample sizes in parentheses after individual ages and 95% confidence limits after A_{50} (yr).

Age (yr)	1959-1964	1965-1969	1970-1974	1975-1979
		Male		
1	0.0 (37)	0.0 (180)	0.0 (497)	0.0 (406)
2	1.4 (73)	3.4 (118)	3.6 (770)	8.3 (653)
3	5.6 (89)	33.5 (182)	44.0 (693)	57.5 (682)
4	32.1 (156)	87.4 (215)	87.9 (306)	92.9 (629)
5	50.0 (60)	77.7 (202)	97.6 (294)	99.8 (545)
6	75.0 (32)	92.7 (234)	98.7 (230)	100.0 (288)
7	92.9 (14)	100.0 (46)	99.1 (324)	100.0 (159)
8	100.0 (11)	100.0 (13)	98.0 (254)	100.0 (49)
9	100.0 (5)	100.0 (6)	100.0 (91)	100.0 (26)
A_{50}	4.74(4.52-4.98)	3.35(3.23-3.48)	3.16(3.10-3.23)	2.83(2.78-2.88)
		Female		
1	0.0 (14)	0.0 (172)	0.0 (405)	0.0 (334)
2	0.0 (73)	0.0 (110)	2.5 (770)	9.5 (778)
3	5.7 (105)	14.8 (128)	27.2 (665)	45.2 (733)
4	30.6 (183)	88.8 (322)	83.5 (316)	81.9 (586)
5	61.5 (130)	51.6 (184)	98.9 (261)	99.4 (520)
6	82.1 (67)	88.1 (293)	99.5 (191)	99.0 (286)
7	91.5 (47)	97.2 (107)	98.9 (368)	100.0 (179)
8	100.0 (34)	100.0 (30)	100.0 (312)	100.0 (72)
A_{50}	4.61(4.45-4.78)	3.61(3.47-3.75)	3.37(3.30-3.44)	3.02(2.97-3.08)

Table 6. Median length at sexual maturity and 95% confidence limits of haddock in NAFO Subarea 4 as determined from Canadian groundfish surveys from 1959-1964, 1965-1969, 1970-1974, and 1975-1979.

	Males			
Division	1959-1964	1965-1969	1970-1974	1975-1979
4Vn	40.82 (39.58-42.09)	-	39.92* (36.46-43.73)	
4Vs	38.30 (37.19-39.45)	38.90 (36.28-41.71)	38.59 (36.71-40.57)	40.16 (36.94-43.65)
4W**	37.99 (37.68-38.31)	38.10 (37.58-38.62)	34.99 (34.51-35.47)	38.81 (38.61-39.02)
4X	40.52 (39.85-41.20)	38.34 (37.94-38.75)	39.32 (38.92-39.72)	37.05 (36.75-37.35)

	Females			
Division	1959-1964	1965-1969	1970-1974	1975-1979
4Vn	46.71 (45.75-47.69)	-	41.55* (35.45-48.71)	
4Vs	43.79 (42.66-44.95)	43.03 (37.11-49.90)	39.69 (36.74-42.88)	38.49 (36.48-40.61)
4W**	42.64 (42.35-42.93)	42.50 (41.95-43.05)	41.04 (40.60-41.50)	41.85 (41.62-42.08)
4X	43.08 (43.14-44.47)	40.40 (39.98-40.82)	42.32 (41.92-42.72)	40.56 (40.14-40.78)

*Data for 4Vn were grouped from 1970-1979.

**Data for 4W were grouped from 1958-1964.

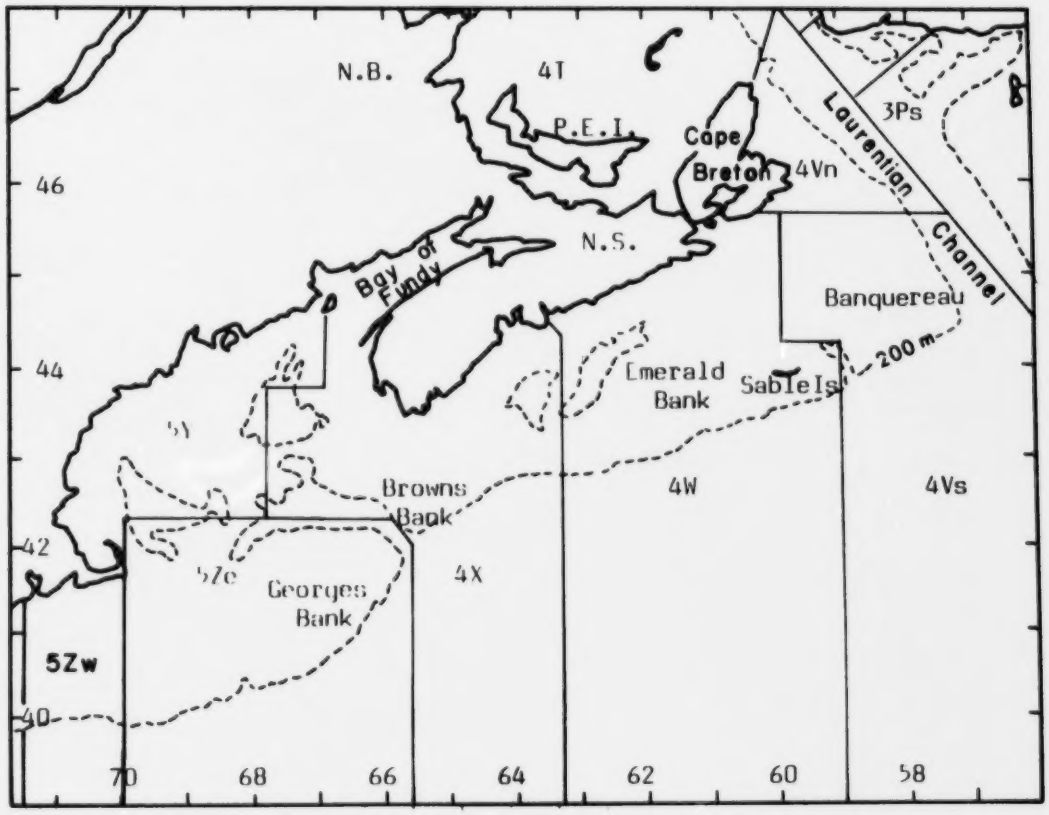

Fig. 1. Northwest Atlantic Fisheries Organizations Divisions in Subarea 4.

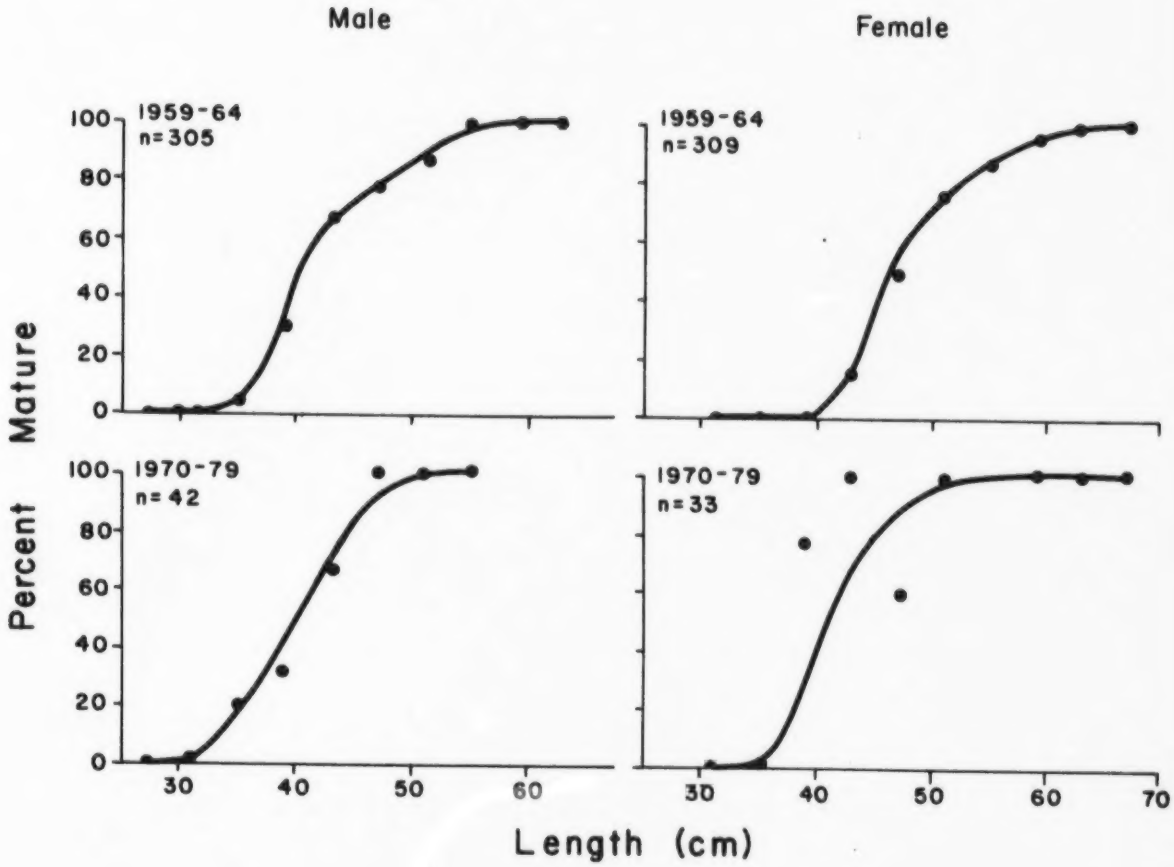

Fig. 2. Maturity ogives for haddock caught during Canadian groundfish surveys on Subdivision 4Vn, 1959-1979.

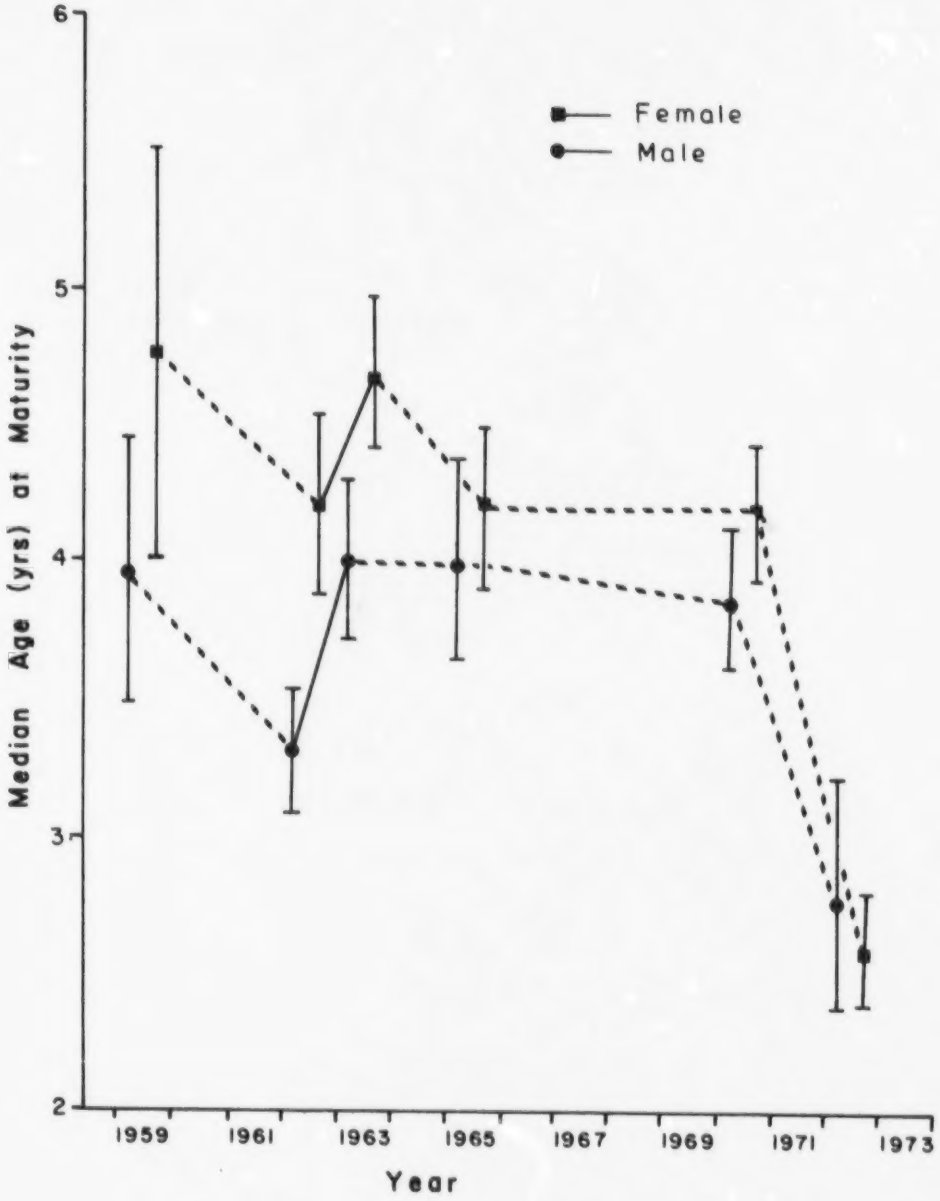

Fig. 3. Median age at sexual maturity for haddock caught during summer groundfish surveys in Subdivision 4Vs, 1959-1972.

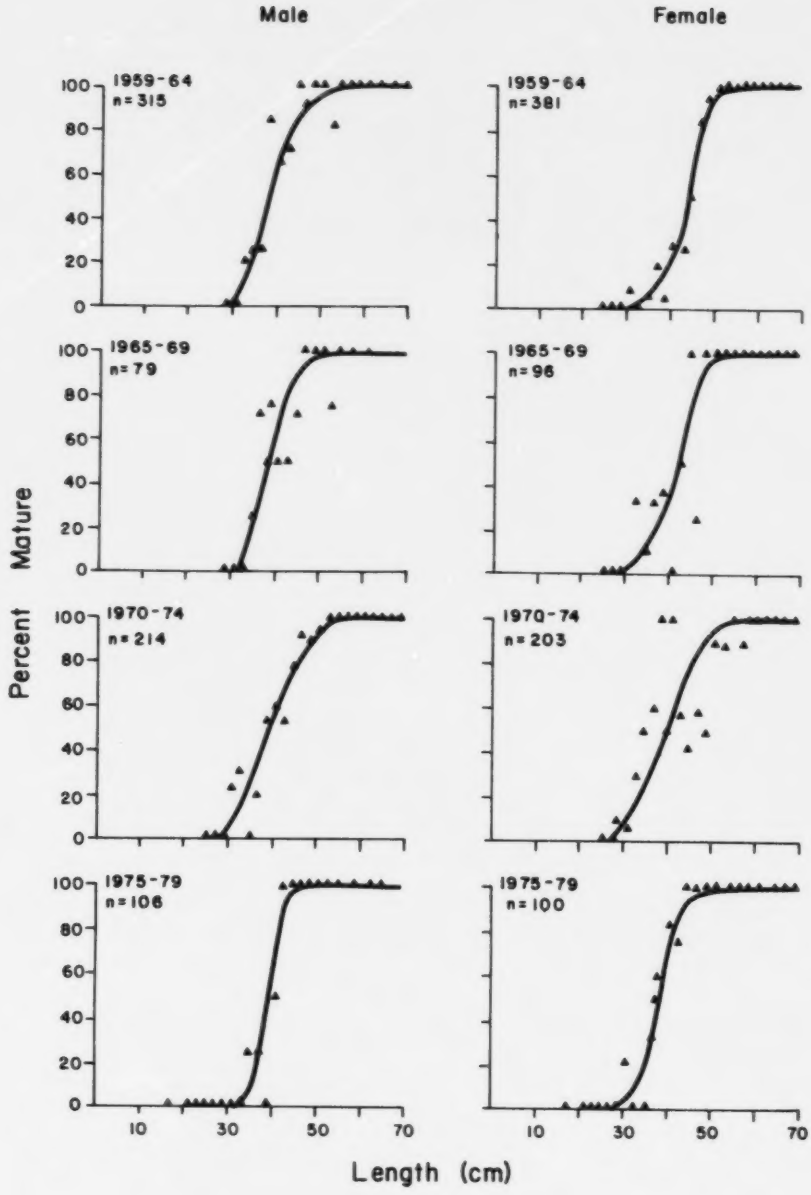

Fig. 4. Maturity ogives for haddock caught during Canadian groundfish surveys in Subdivision 4Vs, 1959-1979.

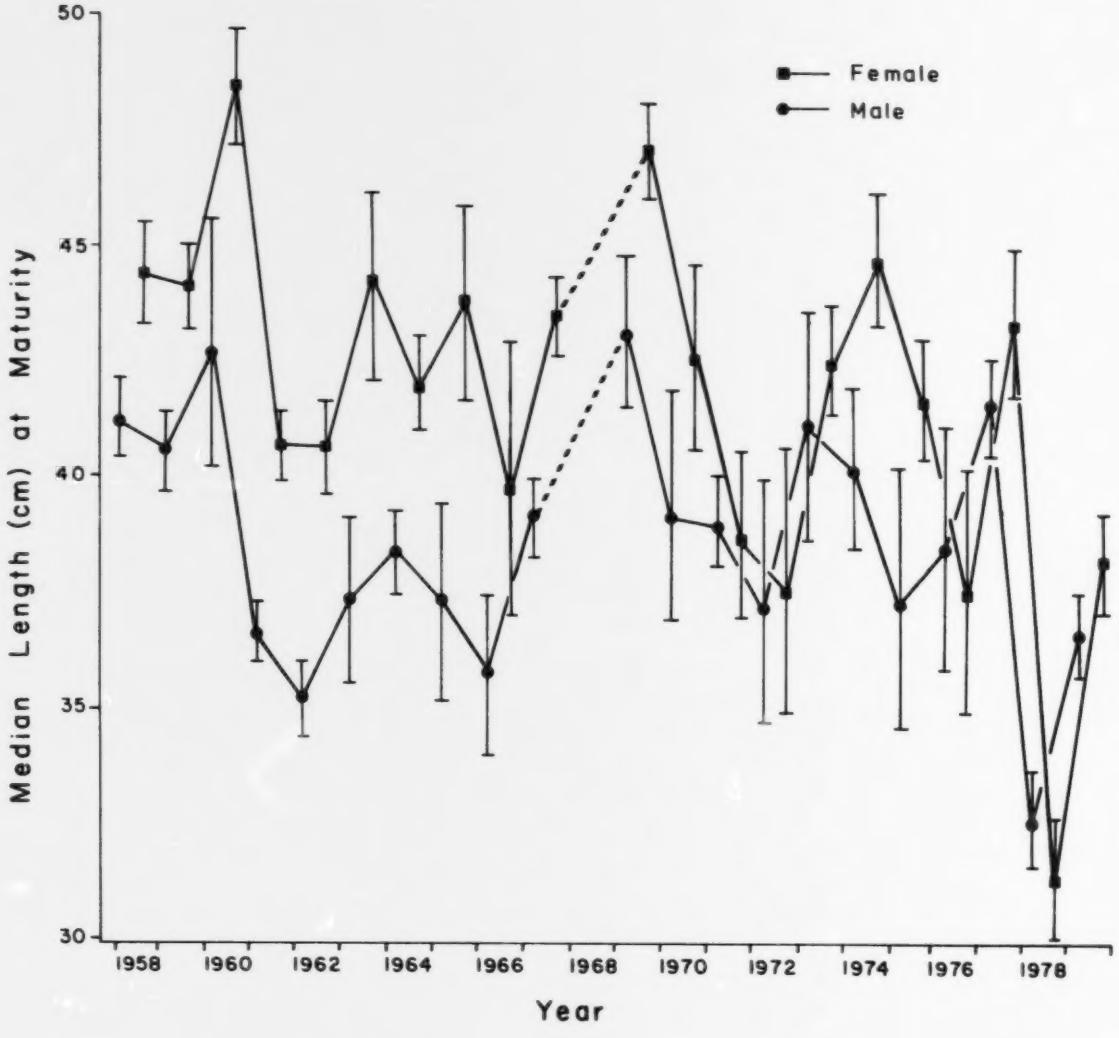

Fig. 5. Median length at sexual maturity for haddock caught during summer groundfish cruises in Division 4W, 1958-79. Vertical bars indicate 95% confidence limits.

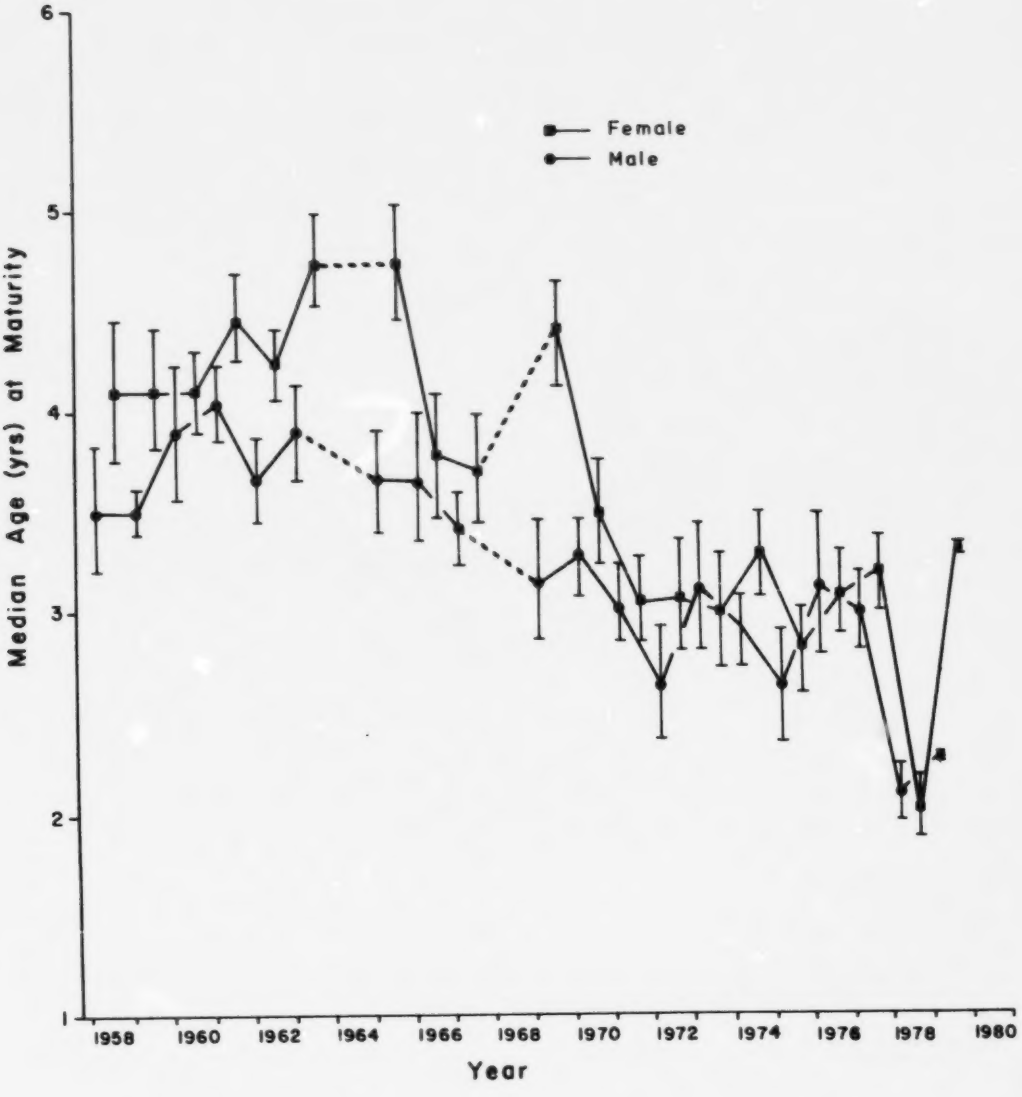

Fig. 6. Median age at sexual maturity for haddock caught during summer groundfish cruises in Division 4W, 1958-79. Vertical bars indicate 95% confidence limits.

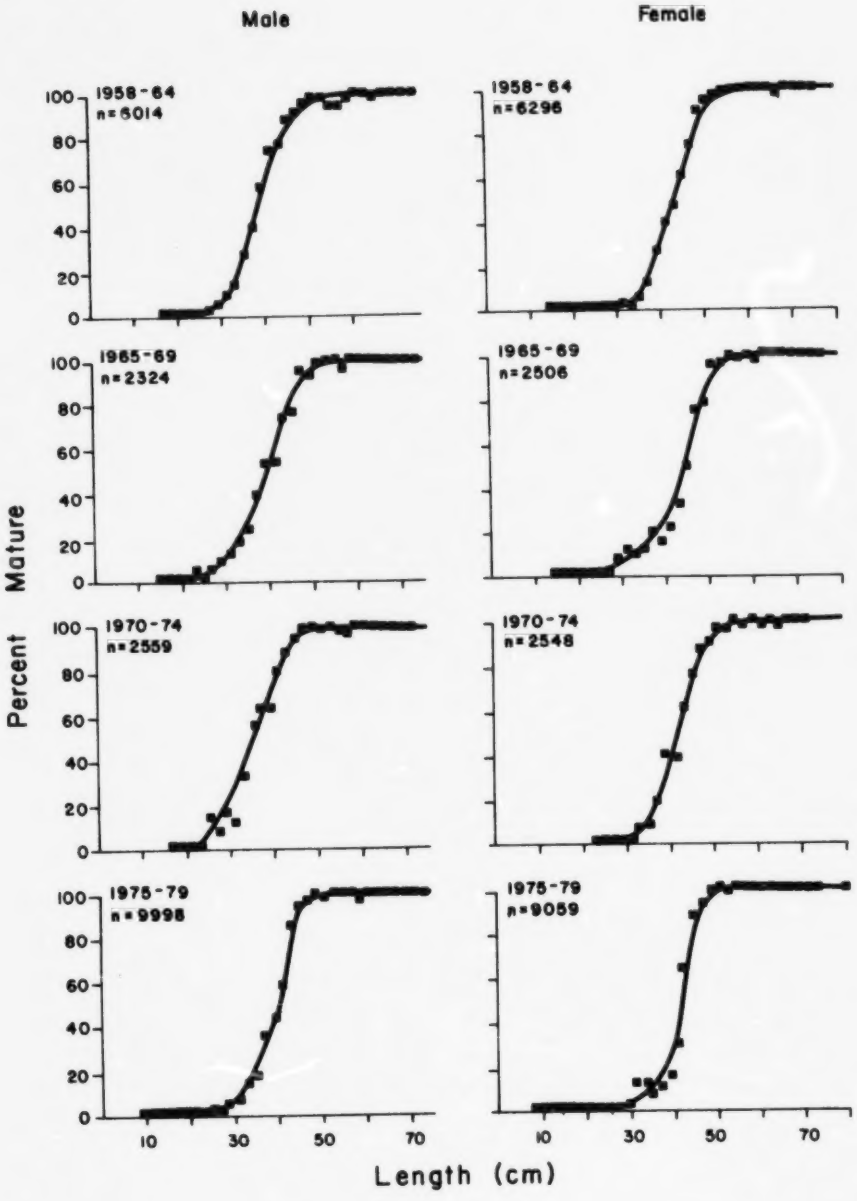

Fig. 7. Maturity ogives for haddock caught during Canadian groundfish surveys in Division 4W, 1958-79.

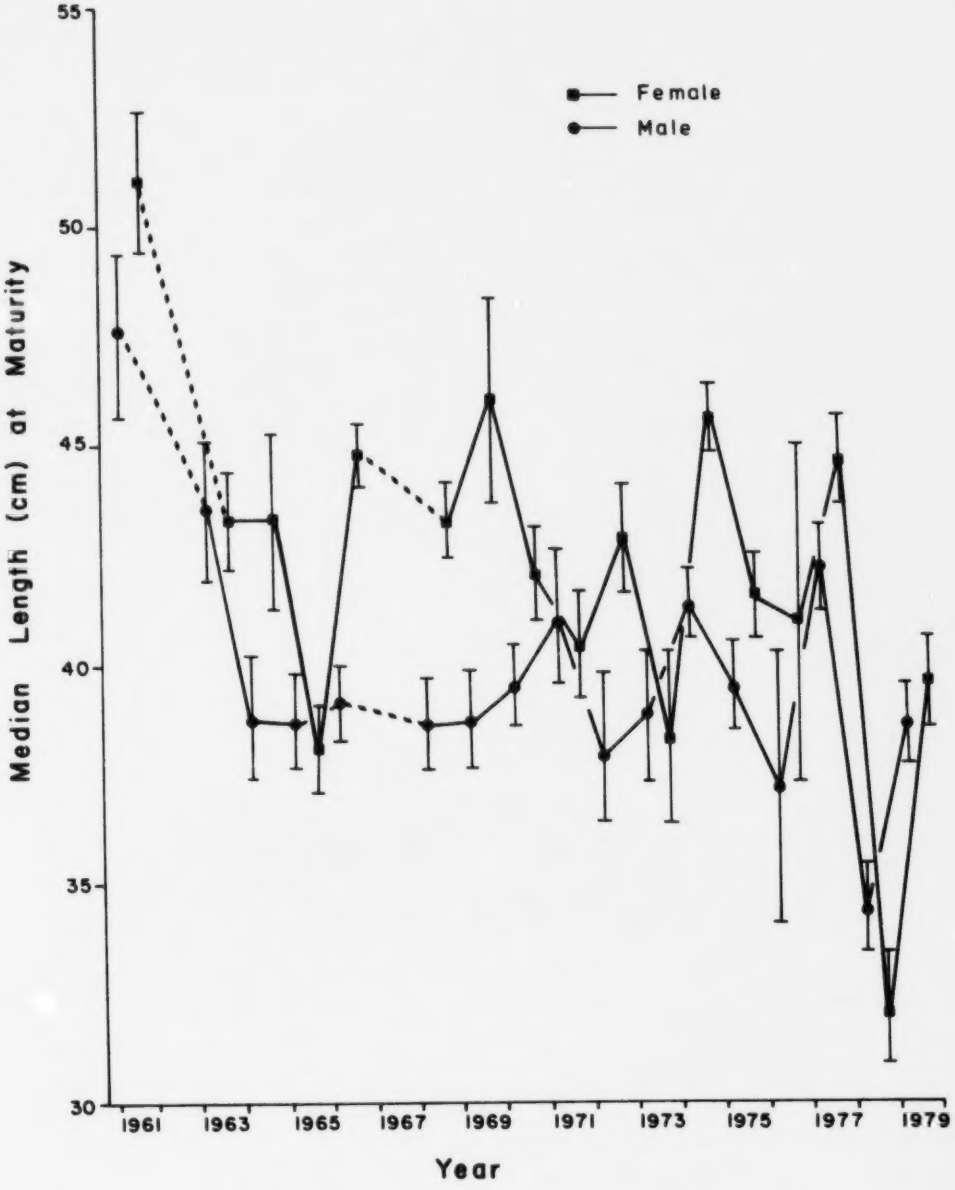

Fig. 8. Median length at sexual maturity for haddock caught during summer groundfish cruises in Division 4X, 1959-79. Vertical bars indicate 95% confidence limits.

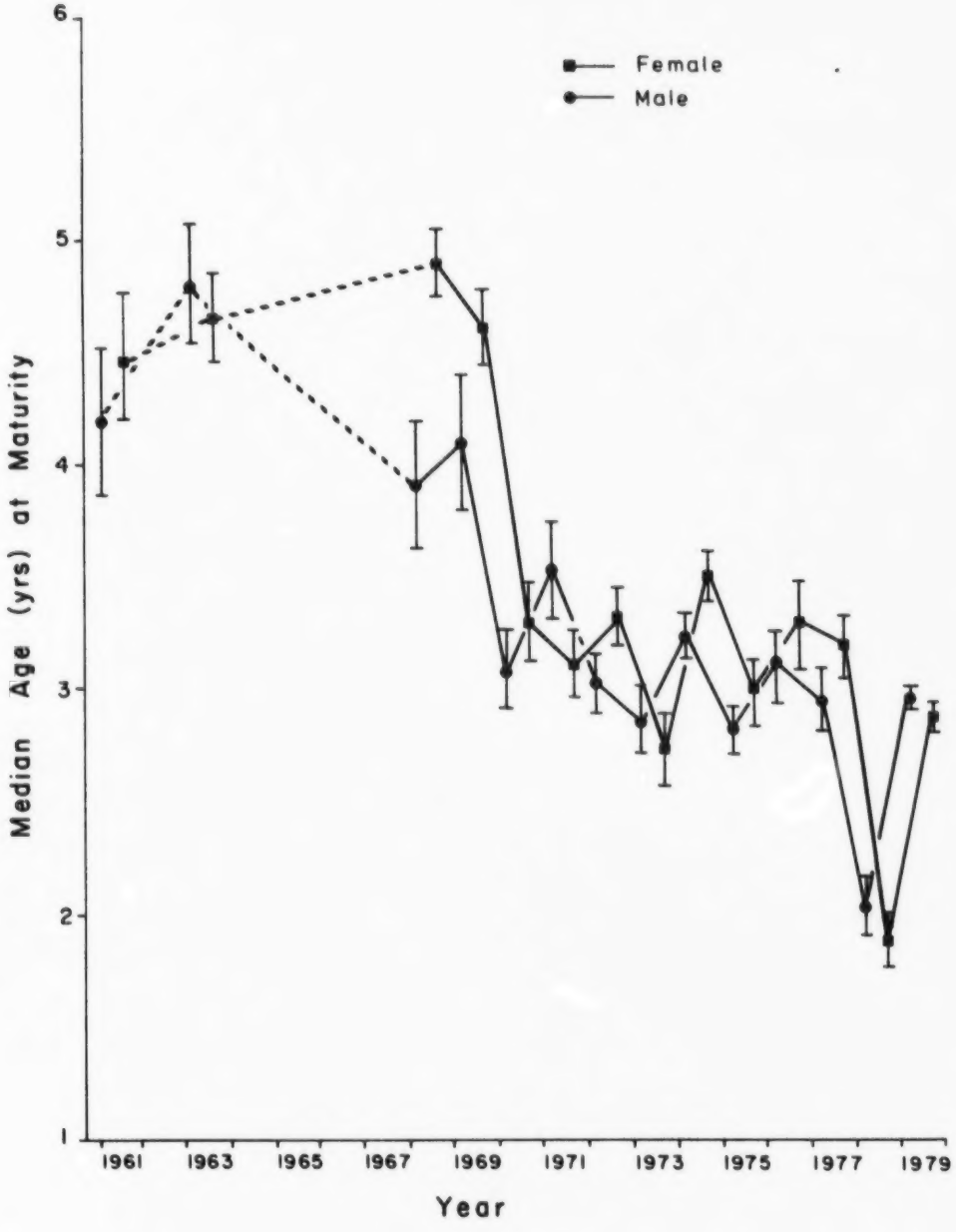

Fig. 9. Median age at sexual maturity for haddock caught during summer groundfish cruises in Division 4X, 1959-79. Vertical bars indicate 95% confidence limits.

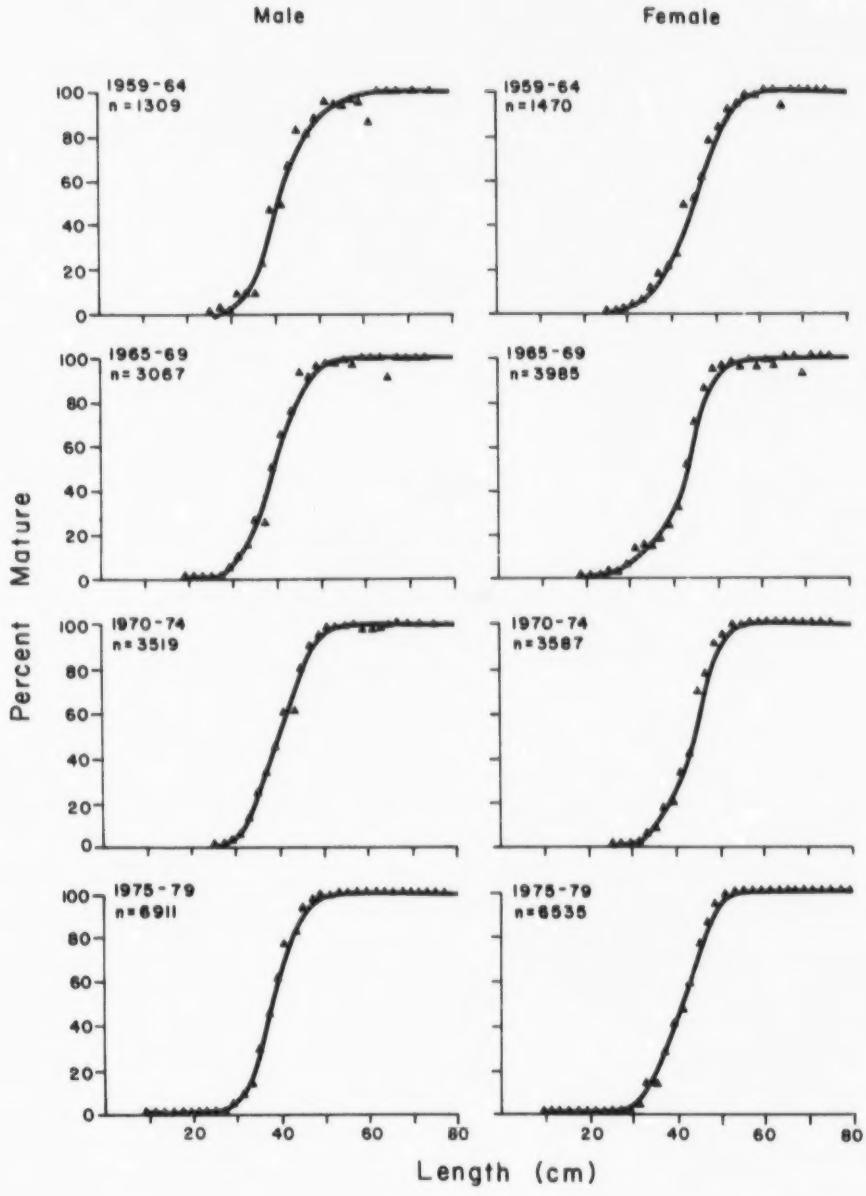

Fig. 10. Maturity ogives for haddock caught during Canadian groundfish surveys in Division 4X, 1959-79.